Study of Power Drops in a Transmission Line in The Case of Linear Antennas

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Abstract--This paper studies the power drop in a transmission line for linear antennas. This study was conducted to recover the power lost due to infinite resistance created by the vacuum in the transmission line and was done in the Physical Science Laboratory of the University of Maroua and on the site of the 93.5FM radio station in Meiganga in the Adamaoua region of Cameroon between March 2019 and January 2020. To achieve our goal, theoretical calculations were made on all the equipment involved in the production of radio signal, especially those located upstream of the transmitter, to better appreciate the practical results. After performing the theoretical calculations, a fictitious load was used to locate the origin of the failure, then a detailed algorithm was implemented to clearly show the different steps of the problem resolution. The results obtained during this manipulation show that the power drop is created not only by an infinite amount of resistance due to equipment collapses, but also by water infiltration into the distribution frame. After evacuating the water in the distribution frame, the previously lost power was recovered by reinforcing the different connection points between the equipment in the transmission line.

Keywords--Power drop, transmission line, linear antenna, infinite.

I. Introduction

A radio wave transmitter is an electronic telecommunications equipment that radiates electromagnetic waves into space through an antenna [3]. The signal transmitted by these radio waves can be a broadcast program a remote control, a conversation, a computer data link [7], etc. However, it occurs during signal transmission, situations where the power generated by the final amplifier of the antenna no longer covers a large range despite the fact that there are no obstacles related to the environment (relief, vegetation, etc.). This is due to the power drop that occurs in the transmission line, the electrical power sent to the dipoles is instead returned to the transmitter. This phenomenon is a handicap not only for the listeners who are patiently waiting for the signal to be received at the receiver, but also for the production equipment and can damage the latter [1]. It is therefore obvious to have a good knowledge about the manifestation and resolution of these harmful phenomena in the transmission of electromagnetic wave signals. In this article, we will study this power drop and we will present its causes, the equipment used, the methodological approach, the results obtained, and finally a conclusion followed by recommendation.

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II. Materials and Methodologies

II.1 Equipment

In the circuit in the figure below (Figure 1), the load barrier (40,5Ω) is not equal to that of the source and transmission line (50 Ω) [10]. For this reason, part of the signal propagating through the transmission line is reflected from the load.

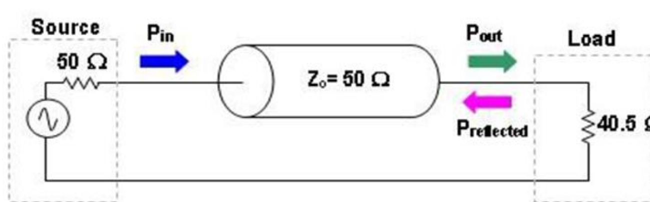

Figure 1: Characteristic diagram of a transmission line

In a transmission line, an incident wave of amplitude Vi and a reflected wave of amplitude Vr coexist. The superposition of these two waves will produce a resulting wave whose amplitude will vary along the line [3]. Maximal will be observed where the incident wave and the reflected wave produce constructive interference Vmax=Vi+Vr and vice versa, minimal will be observed where the two waves produce destructive interference Vmin=Vi-Vr. The SWR (Standing Wave Ratio) is defined by the ratio of the extremes:

$$\mathbf{VSWR} = \frac{\mathbf{Vmax}}{\mathbf{Vmin}} = \frac{(\mathbf{Vi+Vr})}{(\mathbf{Vi-Vr})} \quad (1)$$

Let us consider a radio transmitter, with output impedance Zs, feeding an antenna, whose impedance is Za through a transmission line characterized by a characteristic impedance Zc [1]. The transmission line is thus terminated on a load with an impedance equal to its characteristic impedance; it is said to be matched at the output and at the input. If these impedances are not equal, the VSWR can be calculated as follows:

$$\{\mathbf{VSWR} = \frac{Zc}{Za} \textbf{ when } \mathbf{Zs} \geq \mathbf{Za};\ \mathbf{VSWR} = \frac{Za}{Zc} \text{ if } Zc < Za\} \qquad (2)$$

When VSWR=1, all energy supplied by the transmitter is accepted by the antenna and radiated as electromagnetic waves [4]. However, if VSWR > 1, some of the energy is returned from the antenna to the transmitter (i.e., an incident wave from the transmitter to the antenna and a reflected wave from the antenna to the transmitter are simultaneously transmitted). The superimposition of these two waves in the line causes standing waves to appear (Figure 2) [10] at certain points in the line. The presence of standing waves on a transmission line can have another negative effect, that of reaching the breakdown voltage of the line.

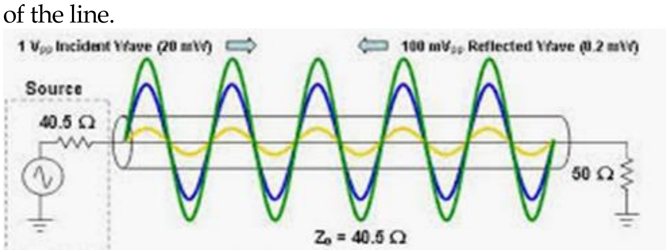

Figure 2: Example of wave movement along a transmission line

Similarly, the modulus of the reflection coefficient is obtained by dividing the amplitude of the reflected wave by the amplitude of the incident wave. The result may vary between 0 (perfect impedance adaptation: no reflected wave) and 1 (total reflection: case of an open or short-circuited line) [1]. By convention we note the reflection coefficient module ρ.

$$\rho = \frac{\textbf{Reflected}}{\textbf{Direct}} \qquad (3)$$

The relationship between **VSWR** and the reflection coefficient ρ is as follows:

$$\mathbf{VSWR} = \frac{(1+\rho)}{(1-\rho)} \qquad (4)$$

II.2 METHODOLOGIES

The example that we will show is a practical case that we met in a community radio station 93.5 FM. The radio station transmitting on 93.5FM, which delivers a power of 1000W at the output of an amplifier, had its power reduced to a quarter of its nominal value (250W). We found that the radio signal, which could be picked up in a radius of more than 80 km, was only perceptible on a radius of 7 km. The question is to know the causes of this power drop and how to remedy it?

To recover the power lost by this transmitter, the methodological approach is as follows.

- **Theoretical calculations**

The resistance of the dipoles: For a system of four dipoles (04) and the resistance of each dipole is 50Ω, to find the equivalent resistance of the assembly, proceed as follows:

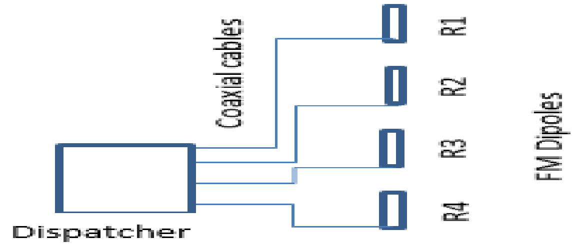

Figure 3: illustrative diagram FM dipoles

$$\frac{1}{\mathbf{Requi}} = \frac{1}{\mathbf{R1}} + \frac{1}{\mathbf{R2}} + \frac{1}{\mathbf{R3}} + \frac{1}{\mathbf{R4}} \qquad (5)$$

Requi=12,5Ω this verifies well the resistor grouping theorem, which postulates: when we have several resistors grouped in parallel, the equivalent resistance of the set must be lower than the lowest value of the resistance of the set [8]. We are in the case of a well closed transmission line with a load of 50 Ω, since the dipoles are in parallel, a load of 50 Ω is sufficient to start the basic exciter.

The feeder and the distributor are superconductors, their resistance is negligible.

The resistance of the coaxial and the thermal effects as a whole cannot lead to an infinite resistance according to the illustrative assembly diagram of the equipment used.

After theoretical calculations judiciously carried out on all the equipment, this value is less than or equal to 50 Ω according to the assembly of the equipment used. In order to confirm these theoretical values, we carry out practical measurements using measuring devices such as multimeters.

- **Practical measurements**

The measurement made on the feeder and all the well-connected upstream equipment consisted in first disconnecting the feeder from the RF terminal of the power amplifier and placing the two outputs of the multimeter on the plus (+) and minus (-) of the feeder. The well-calibrated digital multimeter shows us a resistance value of the order of mega ohms. This is far from the theoretical value calculated previously, by performing this measurement we expect to obtain a resistance value less than or equal to 50 Ω. Based on the laws and theorems used in electronics, such as the famous ohm's law (U=RI), we quickly thought of vacuum, because based on the ohm's law, vacuum can be the origin of this infinite resistance in this transmission line whose theoretical values have been well determined in advance [9]. Since the resistance has given us an infinite value, it is obvious that the current flowing through the line is negligible. [5]. Faced with this inconsistency between the two results, it turns out that the vacuum was created in the transmission line either by sagging of the equipment, and the contact is no longer frank between certain connection points, or some other phenomenon such as atmospheric humidity or rainwater can infiltrate the splitter and also create the power drop during signal transmission. It is therefore a question of eliminating this infinite resistance, in order to recover the lost power.

On the front panel of the amplifier below (figure 4), an

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LCD screen and status lights are present to indicate the main values and the working status of the unit. Next to the LCD screen, there are also 4 push buttons for easy navigation (loading values, entering the amplifier menu, etc.).

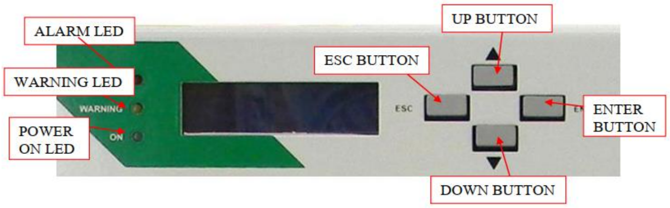
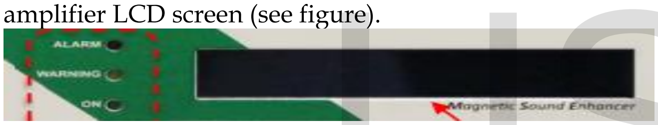


Figure 4: Panel interface

To access the values of the displayed measurements, you can also enter the power menu by pressing enter and see the measurements of the direct output power (FWD OUT) and the reflected output power (REFL OUT). For each amplifier module, it is possible to access the internal voltage (Vpa) and current (Ipa) measurements in the voltage/current menu.

Figure5:current/voltage

While the radiator temperature can be read in the temp/eff menu. Each time an alarm appears on the equipment, the alarm indicator light will illuminate on the front panel and the type of alarm will be displayed on the amplifier LCD screen (see figure).



LCD Display

Figure6: Display screen

When there is no output (alarm reflected), the causes can be: an infinite number of resistance or

water infiltration in the distributor. In both cases, check the integrity of the output load (antenna, feeder, splitter, etc.), check the output of the amplifier connector and make sure the connection is good.

If there is no output power and the alarm message is (system alarm), check the

second message on the screen. This may be due to the temperature of the heater being too high or the presence of VSWR (Standing Wave Ratio) on the output (reflection).

It can also be that there is nothing at the output and no alarm. In this case, increase the power output

in the Logic and Control Unit menu. Increase the output power of the basic exciter and then adjust the output power of the amplifier to the desired level.

Enter the menu [2] Power set. Press the OK button to enter the program mode (the arrow in the second row on the

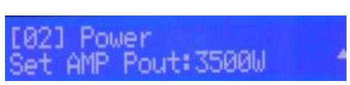


Figure7: Exciter menu

The case where the output power is below the nominal value and no alarm or, warnings do not

signal (module could be damaged) enter the menu and check if the output power is set below the nominal value (SET FWD different from FWD) and check the voltages and currents in the RF module on the display to understand if a power supply or RF module is damaged.

- **Detailed algorithm**

The alarm is switched on when a warning event is recognized or a parameter is saved, and is automatically switched off when the event ends without the need to reset it. In our case either the system alarm or reflected alarm.

Figure8: Alarm system

- Locate the fault: Is it an internal fault? or external?
- Carry out theoretical calculations on all equipment (Feeder, dispatcher, etc.), coaxial, dipoles) the theoretical values found, will help us to make a comparison with those found during practical measurements.

Connect a dummy load of 50 ohms to the RF (Radio Frequency) terminal of the amplifier with a precise RF output, automatically controlled by the level of the power amplifier stage. The RF power, temperature, voltage and current drawn by the power amplifier board are shown on the LCD graphic display screen (see figure below).

Figure 9: The display screen

- When the load is connected attention is focused on the alarm. In other words, the alarm either disappears or continues to signal. In the first case, the basic exciter will continue to transmit the signal normally, and you are reassured that there is no internal fault. In the second case the alarm will continue to signal and it is deduced that the fault is external and the next steps are well known. In both cases, the basic exciter still emits a signal but over a short range. In the case of an inner failure, test the components until the problem is detected. This requires a great deal of care, especially in the handling of the measuring and test equipment. Depending on the type of measurement being undertaken, different preliminary steps are necessary. In all cases, the points where the multimeter is to be connected must be determined precisely and the cables or connectors must be fitted to the multimeter. For voltage and current measurement, select the appropriate operating mode (- direct or ~ alternating), then select the gauge (the largest possible value). For resistance, diode threshold voltage, or continuity measurements, disconnect the power supply, isolate the component or circuit to be tested if necessary. The choice of rating is therefore an important prerequisite for any measurement, otherwise the device may be damaged, at best a blown fuse, or a damaged measuring device, or worse, a destroyed circuit in the course of measurement. If, as a result of a wrong choice of gauge, the digital multimeter indicates

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a strange value (generally it displays "1." on the far left), or for an analog multimeter, the needle hits one of the stops on the left or right, disconnect the instrument immediately, then choose a higher gauge. And if the fault is external, i.e. the second case, we start by measuring all the upstream equipment.

- Short-circuit the feeder, and test its continuity as well as the value of its resistance, if it proves to
- be close to theoretical results (the feeder being a superconductor of negligible resistance and attention must be paid to its continuity), we move on to the next step.
- Test the splitter to make sure it is working properly. It is therefore advisable to check first, for water
- infiltration in its parts. If there is water infiltration, empty it completely and then ring all its terminals. If this step is verified, and the results are positive, then continue with the next step.
- Ring all the dipoles and also read their resistances (FM dipoles have generally each a 50 Ω resistor)
- After all verifications and measurements have been made, reconnect all the elements

and strengthen connection points. Carry out a no-load test, i.e. redo the measurement of the assembly (feeder, splitter, dipoles) before connecting it to the RF terminal of the amplifier. This value allows us to see if there is still a coherence between the theoretical values found previously and the practical measurements. If the displayed value is the same or close to the theoretical value, the vacuum that created an infinite resistance in the line has been removed and we can find the powers lost when the transmitter is started up again. In other words, all the powers are sent to the dipoles and radiated by them as an electromagnetic wave and then picked up over a good distance as defined by its frequency (no reflected power).

Starting the transmitter, while making sure that the antenna is properly connected to the output filter

or amplifier output, that the alarm and warning lights are off. The problem is solved and the lost powers are recovered, the powers delivered at the RF output of the amplifier are accepted by the dipoles.

All these methodological steps have been summarized by the diagram below

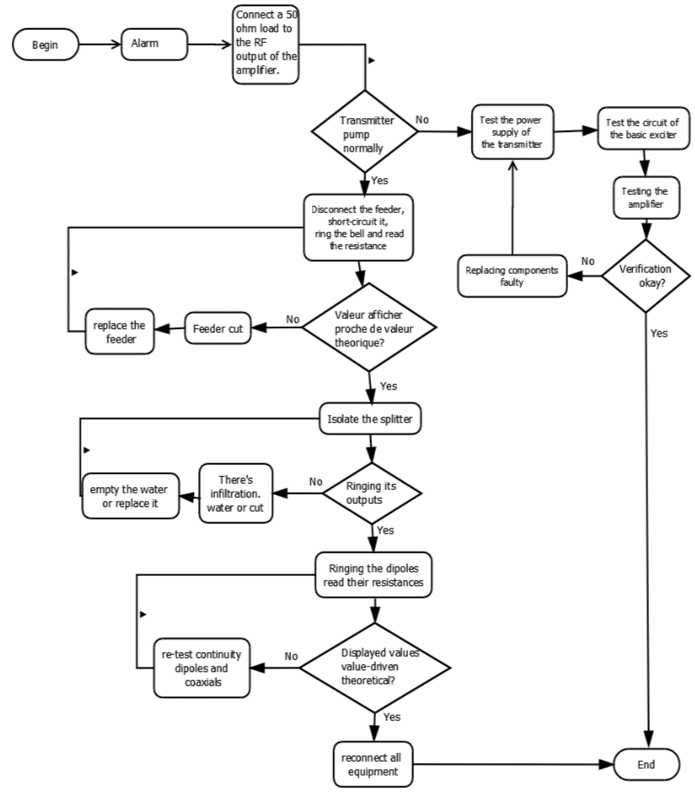

Figure10: Detailed resolution algorithm

III. Results achieved and discussion

The objective of our work was to study the power drop in the transmission line in the case of linear antennas. Experimentally, we were able to show that the power drop that occurs along a transmission line, characterized by the presence of standing wave ratios, has an immediate impact on the equipment used in broadcasting and the electrical signal radiated by the dipoles as an electromagnetic wave in space. Thus, the carrier of the signal is reduced and the signal is noisy and not perceptible over a long distance (the range is reduced).

The transmission line used in our case, is closed on an impedance lower or equal to 50 ohms. Impedance matching is obtained when the source impedance is the complex conjugate of the load impedance [9]. When there is an offset between the load impedance and the transmission line, part of the forward wave sent to the load is reflected along the transmission line to the source (reflected power) [6] and the alarm is triggered (see figure 8). Thus, in case of this sudden problem creating a deep mismatch in the load, the directional coupler reveals a high level of reflected power suddenly present (more than 10% of the nominal output power) and the VSWR alarm will appear on the front panel with the red symbol and, after a few seconds, the system increases the power again with a soft start to check if this is due to a temporary problem or a stable problem. The unit will then continue to make attempts to check if the problem is still present for 10 times, and then the unit will enter the system alarm mode stably and then have to be manually switched off. Both the "warning" and "alarm" lights on the front panel will illuminate, and the amplifier will enter the system alarm status by indicating system alarm and reflected alarm on the LCD screen (see Figure 6). The source will then see a different impedance than expected which may lead to less (or in some cases, more). A suitable load would result in an SWR of 1 (the source impedance is equal to the load impedance Zs = Zc) [3] which implies no reflected waves (all powers emitted by the transmitter are accepted by the dipoles) and the antenna radiates normally and the range goes as far as possible with perfect reception quality therefore an infinite SWR represents the total reflection by a load unable to absorb the electrical energy, with all the incident power reflected back to the source (see Figure 2), which will have a direct impact on the range and signal quality received by the listeners at their receiving stations (the signal range is reduced, the signal quality is noisy and thermal power dissipation in the equipment may also occur). The incident energy is totally reflected back to the signal source through the transmission line and two phenomena explain this, either a vacuum created by the collapse of the transmission equipment and the contact is no longer frank between these equipment's, or by water infiltration in the distributor which is also the cause of power drop in the transmission line. In the first case (case of vacuum), we tested all the equipment according to a well-developed methodology. These tests were carried out with highly sensitive and well-calibrated measuring equipment (the largest possible caliber). Theoretical calculations based on the laws used in electronics have been carried out beforehand in order to better appreciate the practical results. The results obtained by practical and theoretical measurements had a large discrepancy and we continued to isolate each piece of equipment in order to have a precision on their operating states. In a judicious way, we succeeded in locating the fault that was located between the feeder and the dispatcher. Indeed, the contact between the two equipment was no longer frank, creating an infinite amount of resistance, resulting in a power drop in the transmission line. The connections were reinforced at all connection points and by performing the second measurement, the vacuum was completely removed and the lost power was recovered. The transmission power went beyond 80 Km with a better reception quality. However, it is obvious to note that the power drop study remains exploratory in nature and may evolve especially in the case of linear antennas.

IV. Conclusion

In this paper, we have presented the power drop in a transmission line in the case of linear antennas. Following the methodological approaches, we have shown that the power drop that occurs in a transmission line is caused either by an infinite resistance created by a void between the connection of the equipment (non-frangible contact, coaxial cable break, etc.) located upstream of the transmitter, or by water infiltration in the distribution frame. We solved this problem methodically by first proceeding by theoretical calculations based on the laws and theorem used in electricity (ohm's law, resistor grouping theorem, etc...). After obtaining the theoretical value, we tested each piece of equipment using the measuring devices well known in the world of electronics such as the multimeter and the Amperemetric Tester. By measuring at each level and at each connection point of the equipment, we managed to eliminate the vacuum that was created precisely between the feeder and distributor connection. Indeed, the feeder collapsed and the contact was no longer frank between the two equipment's (feeder and splitter), hence the presence of an infinite resistance in the line. The connections were well reinforced and the lost power was recovered with a signal range of more than 80 km with good signal quality.

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