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Analysis of signal interferences between nearby radio stations in Nigeria

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ABSTRACT: This work presents an analysis of signal interferences in radio and television broadcasting in Nigeria. It identifies the existence of interferences between any two or more nearby radio stations. It also identifies the level, the causes and effects of such interferences. These were achieved by conducting both computer simulations (using existing ITU mathematical models) and field experiments to determine certain inherent factors, such as: the minimum field strength, transmit frequency, and area of coverage of a selected number of Radio and Television stations in each of the six geopolitical zones of the country.

KEYWORDS: **Radio, Signal Interference, Management**.

I. INTRODUCTION

Radio wave interference occurs when two or more electromagnetic waves combine in such a way that the performance of a system is degraded. More specifically, interference occurs when two waves occupy the same area of space at the same time(Wayne T,2002). Thus, the occurrence of interference could be prevented, or at least minimized, by preventing two or more electromagnetic waves from occupying the same point in space simultaneously.

As a member nation of the ITU (The International Telecommunications Union), Nigeria is not left out in this global search, particularly, as local needs to accommodate an ever-increasing number of users and offer bandwidth-rich applications become more pressing and challenging than before. The interest, however, narrows down to the study of signal interference in radio broadcast. The significance of this study is to observe and recommend solutions for high concentration of both radio stations in six geographical areas across Nigeria. The paper observes specific broadcasting characteristics that contribute to the prevention of interference among various services and users of the same service frequency band.

This is mainly related to the minimum field strength, transmission frequency, the distance between channels and broadcasting centers, the effective radiated power and the radiation pattern of these Radio Stations. This study aims at investigating the existence of interference between two nearby radio stations. It also aims at determining the cause and effect of such interference in the transmission and reception of Radio signals. Finally, it recommends/ proffers solutions to reduce or totally eliminate such interference in Radio broadcast in Nigeria.

II. METHODOLOGY

Field experiments were carried out to determine minimum field strength in some selected frequency modulated (FM) stations. The coverage distance of each radio station was also established. The obtained result from the experiment was substituted into mathematical model for inference assessment to verify whether interference actually existed.

Experiment 1: Determination of Minimum Field Strength in FM Radio Stations

This experiment was carried out in the transmitting room of the Radio stations in the six radio stations covering the six geopolitical zones of the Nigeria. The aim of this experiment is to measure the Minimum Field Strength of some selected Radio stations within Nigeria. The essence is to compare the actual Minimum Field Strength of the station with respect to the allocated Minimum Field Strength of the station and also to investigate if there interference by using ITU specified mathematical models. The equipment used for this experiment is as follows: 50-ohm dummy load, Wattmeter, Antenna tuner , and Oscilloscope. The connection between the Radio station antenna and the FM transmitter was first removed and all other connections were made using coaxial cable wires. Using the input marked "Antenna", the dummy antenna's coaxial cable was attached to the antenna tuner. Then the Wattmeter was set and was connected to the antenna tuner and the Oscilloscope. Connections were also made between the Oscilloscope and the Transmitter via the input marked "Transmitter". The ground wire was connected. The tuner was set to "In" to measure transmit power and Signal Wave Ratio (SWR) independently. Finally, the corresponding power reading of both the wattmeter and the oscilloscope were taken. This experiment was done every one hour and results were taken for 5 hours. The essence was not to disrupt their program which they change hourly. The averages were then calculated and were tabulated in Table 1.

III. MATHEMATICAL MODELS USED FOR INTERFERENCE ASSESSMENT

This section describes the mathematical models used for this study. The derivation of the models was based on an assumption of a simple scenario involving a directional mobile transmitter operating in the midst of other transmitters in the same operational area. As a result, co- channel and adjacent channel interferences

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were considered, using the following technical parameters of an existing radio system: Minimum Field strength, Transmit Power [TP], Frequency of Operation [FO], Antenna Height [AH] above the local terrain.

- ***FM Radio Stations***

The level of field strength needed to provide adequate reception in the presence of an interfering signal(s) is referred to as the usable field strength (Eu) (Wayne, 2002). The calculation of the effective interference level (Eu) in the presence of a number of sources of interference [due to co-channel (CCI), adjacent channel (ACI) or receiver characteristics] for a particular interfering signal considered to be acting alone is calculated as the algebraic sum of the required RF protection ratio and the field strength of the particular interfering signal in dB (ITU, 2004), as expressed in the equation below.

$$\mathbf{Eu = 10 \log \sum 10^{(0.1Ea)}} \quad \ldots.. \quad 1$$

Where Ea is the voltage of an individual contribution.

If an existing service has its Eu increased by a new or proposed service when calculated by this process, it is considered to suffer interference. A service is said to be protected when planning proceeds on the basis that it will not be allowed to suffer interference as defined above (Fadeyi, 2004).

IV.RESULTS AND DISCUSSION

Analysis of Interference in FM Radio Stations

Evaluating the average of the 5 measurements obtained in the experiment and comparing it with the allocated minimum field strength in each geographical region, the table below was developed. Interference from other services may cause higher levels of field strength to be necessary for an adequate service than the allocated minimum field strengths as stated in Recommendation 499-1 (ITU, 2004). The level of field strength needed to provide adequate reception in the presence of an interfering signal(s) is referred to as the usable field strength (Eu). If an existing service has its Eu increased by a new or proposed service when measured by this process it is considered to suffer or cause interference (Atanda, 2001). A service is said to be protected when planning proceeds on the basis that it will not be allowed to suffer interference as defined above. The results obtained from the experiment 1 are shown in the table below.

Table 1: Selected Radio stations in Nigeria and their Minimum field Strength

REGION	RADIO STATION	OPERATING FREQUENCY (MHZ)	TRANSMITTING ANTENNA HEIGHT (M)	MEASURED MINIMUM FIELD STRENGTH (dBm)					AVERAGE MEASURED MINIMUM FIELD	ALLOCATED MEASURED MINIMUM FIELD	INTERFERENCE EFFECT
				1PM	2PM	3PM	4PM	5PM			
NORTH CENTRAL	Radio 1	99.3	55	41.3	39.8	43.5	39.7	42.7	41.4	39.9	YES
	Radio 2	99.5	45	34.9	42.1	43.9	39.8	43.5	40.8	37.8	YES
	Radio 3	99.9	55	41.5	39.0	43.0	35.2	42.1	40.2	40.2	NO
	Radio 4	100.5	45	36.6	40.3	34.9	42.1	42.2	39.2	38.0	YES
SOUTH SOUTH	Radio 5	93.7	60	34.9	40.3	43.9	39.8	43.5	40.5	41.0	NO
	Radio 6	94.1	70	43.5	40.3	34.9	34.9	39.0	38.5	37.5	YES
	Radio 7	95.9	60	42.7	42.7	39.0	40.5	43.9	41.8	42.0	NO
	Radio 8	98.5	60	43.5	43.5	43.9	40.3	39.8	42.2	40.1	YES
SOUTH WEST	Radio 9	88.9	65	39.0	39.8	39.9	43.5	39.8	40.4	40.0	NO
	Radio 10	89.7	45	42.1	34.9	43.9	43.9	43.9	41.7	42.0	NO
	Radio 11	90.3	45	43.9	40.5	34.9	45.8	39.8	41.0	39.5	YES
	Radio 12	90.4	60	40.9	35.9	42.0	38.9	42.7	40.1	40.0	NO
SOUTH EAST	Radio 13	94.1	45	39.0	34.9	39.0	42.1	39.7	38.9	37.5	YES
	Radio 14	93.4	60	43.9	34.9	39.8	40.5	39.8	39.8	40.0	NO
	Radio 15	93.7	60	39.0	39.0	34.9	40.3	36.8	38.0	36.5	YES
	Radio 16	96.1	45	43.5	34.9	40.5	39.0	42.1	40.0	40.1	NO
NORTH EAST	Radio 17	91.9	45	42.7	43.5	39.8	34.9	39.0	40.0	40.0	NO
	Radio 18	94.6	60	42.7	43.5	43.9	34.9	39.8	41.0	39.5	YES
	Radio 19	99.5	55	39.0	43.9	39.8	39.0	34.9	39.3	38.5	YES
	Radio 20	103.5	60	40.5	40.3	40.3	34.9	40.5	39.3	39.5	NO
NORTH WEST	Radio 21	90.9	60	43.9	42.1	34.9	39.0	43.5	40.7	41.0	NO
	Radio 22	96.1	60	39.8	40.5	34.9	39.8	42.7	39.5	39.0	YES
	Radio 23	97.7	55	39.0	40.3	39.0	34.9	42.2	39.1	39.5	NO
	Radio 24	106.5	45	34.9	39.0	34.9	40.5	37.1	37.3	36.5	YES

- ***Calculation of Intermodulation Interference between these FM services***

Very strong FM signals may generate harmonics or intermodulation products in the RF stages of Radio receivers, which can cause interference. This form of interference occurs in the presence of one or more strong unwanted signals when the nonlinearity of a receiver front end generates intermodulation products (ITU, 2009). This falls within the bandwidth of the receiver tuned to the wanted service. Using the expression in the model (ITU,2004) $\mathbf{2 \times f_1 + f_2 = f_3}$; the measured results obtained in the experiment were evaluated for each geographical region to confirm if there is interference. Calculating for the region, the table is developed below.

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Table 2 Intermodulation Interference between FM services

REGION	RADIO STATION	OPERATING FREQUENCY (MHZ)	F=2×F + F	INTERMODULATION INTERFERENCE EFFECT
NORTH CENTRAL	Radio 1	99.30	99.10	YES
	Radio 2	99.50	99.10	YES
	Radio 3	99.90	100.50	NO
	Radio 4	100.50	99.90	YES
SOUTH SOUTH	Radio 5	93.70	99.70	NO
	Radio 6	94.10	89.70	YES
	Radio 7	95.90	95.90	NO
	Radio 8	98.50	89.70	YES
SOUTH WEST	Radio 9	88.90	87.90	NO
	Radio 10	89.70	89.70	NO
	Radio 11	90.30	88.90	YES
	Radio 12	90.40	90.40	NO
SOUTH EAST	Radio 13	94.10	96.10	YES
	Radio 14	93.40	93.40	NO
	Radio 15	93.70	96.10	YES
	Radio 16	96.10	96.10	NO
NORTH EAST	Radio 17	91.90	91.90	NO
	Radio 18	94.60	103.50	YES
	Radio 19	99.50	103.50	YES
	Radio 20	103.50	103.50	NO
NORTH WEST	Radio 21	90.90	109.90	NO
	Radio 22	96.10	97.70	YES
	Radio 23	97.70	95.70	NO
	Radio 24	106.50	90.90	YES

- ***Calculation of Interfering Signal levels***

The root-sum-square (RSS) method is used to calculate the total interference contribution involving a number of interfering transmissions (Akinyele and Ojebode, 2009). This is done using the relationship below.

$$\mathbf{Eu = 10 \log \sum 10^{(0.1Ea)}}$$

where: Ea is the voltage of an individual contribution.

Using the above formula, the individual values of usable field strength (Ea) of the wanted service is thus calculated below.

For Radio 1:

(a) Co-channel interference (CCI) from a distant transmitter with an estimated field strength of 37.8 dBµV/m of Radio 2

(b) Adjacent channel interference (ACI) from a nearby transmitter with estimated field strength of 40.16 dBµV/m of Radio 3

Then the individual interference contributions would be as follows:

(a)Co-channel Interference: The required wanted to unwanted signal strength ratio for protection against co-channel tropospheric interference is 37 dB;

Ea = 37 + 37.8 = 74.8 dBµV/m

(b)Adjacent Channel Interference: The required wanted to unwanted signal strength ratio for protection against adjacent channel continuous interference is 27 dB;

Ea = 27 + 40.16 = 67.16 dBµV/m

Total Ea= 74.8 dBµV/m+67.16 dBµV/m= 141.96 dBµV/m

Then substituting in the general formula, the resultant RSS value (Eu)

Eu = 10 log ∑10 (0.1 x 141.96) = 50.8 dBµV/m

From the above calculation, if an existing service has its Eu increased by a new or proposed service when calculated by this process it is considered to suffer interference (Akinyele and Ojebode, 2009).

Calculating for the remaining region, the table below is developed.

Table 3 Interfering Signal levels Effect

REGION	RADIO STATION	AVERAGE MEASURED MINIMUM FIELD	Eu(dBm)	INTERFERENCE EFFECT
NORTH CENTRAL	Radio 1	41.40	50.80	YES
	Radio 2	40.84	50.76	YES
	Radio 3	40.16	40.19	NO
	Radio 4	39.22	54.87	YES
SOUTH SOUTH	Radio 5	40.48	40.50	NO
	Radio 6	38.52	54.98	YES
	Radio 7	41.76	42.00	NO
	Radio 8	42.20	65.00	YES
SOUTH WEST	Radio 9	40.40	40.43	NO
	Radio 10	41.74	41.78	NO
	Radio 11	40.98	63.98	YES
	Radio 12	40.08	40.10	NO
SOUTH EAST	Radio 13	38.94	39.00	YES
	Radio 14	39.78	39.50	NO
	Radio 15	38.00	43.78	YES
	Radio 16	40.00	40.09	NO
NORTH EAST	Radio 17	39.98	40.00	NO
	Radio 18	40.96	48.90	YES
	Radio 19	39.32	50.34	YES
	Radio 20	39.30	38.00	NO
NORTH WEST	Radio 21	40.68	40.99	NO
	Radio 22	39.54	49.88	YES
	Radio 23	39.08	39.10	NO
	Radio 24	37.28	51.65	YES

Using the table, the graph of the first six Radio Station was developed as shown in Figure 1.From the calculated values and figure 1, when 2 point sources are closely related having similar broadcasting characteristics, there is a tendency of interference effects. These signals will try to compete with each other for more coverage area. This increase in Eu could be as a result of some operators who deliberately increase their minimum field strength in order to expand their coverage area or push out these interfering signals. Furthermore, the graph then shows that interference will be produced because two or more signals having similar properties (predominantly, field strength) join together, changing the amplitude or overall

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properties of the desired signal. This interference limits the performance of the broadcasting systems by restricting the operating range, generating error messages, and in extreme cases preventing the successful operation of receivers. This is the reason why at times when listening to some programmes in any of the station; the other station tends not to have a very clear and good reception.

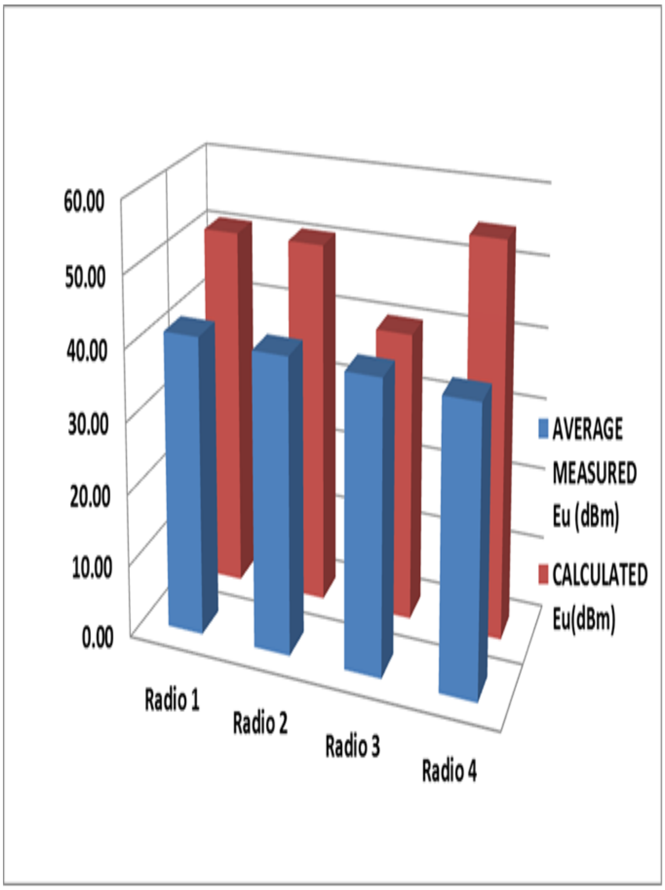

Fig 1: Measured Vs Calculated Minimum Field Strength

From the calculated values and figure 1, when 2 point sources are closely related having similar broadcasting characteristics, there is a tendency of interference effects. These signals will try to compete with each other for more coverage area. This increase in Eu could be as a result of some operators who deliberately increase their minimum field strength in order to expand their coverage area or push out these interfering signals. Furthermore, the graph then shows that interference will be produced because two or more signals having similar properties (predominantly, field strength) join together, changing the amplitude or overall properties of the desired signal. This interference limits the performance of the broadcasting systems by restricting the operating range, generating error messages, and in extreme cases preventing the successful operation of receivers. This is the reason why at times when listening to some programmes in any of the station; the other station tends not to have a very clear and good reception.

V.CONCLUSIONS

From the analysis done in this paper, it was observed that

- Noncompliance of most of the FM radio and television stations do not comply with the technical specifications assigned for their network interfaces
- Threat of interference is a function of the assigned /allocated parameters : minimum field strength, antenna heights, channel separation (bandwidth and spacing), and transmit frequency
- Degradation of service are experienced when the received power levels of an interfering signal are high relative to the desired signal
- Minimum field strength defines

a. the maximum level at the boundary of the coverage area, to protect geographically adjacent users of the same frequencies,

b. the maximum level of out-of-band emissions, to protect users of adjacent frequencies in the same geographical area

- Frequency allocation systems are not clearly designated or are not adhered to by the operators.

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