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Tower Effects on FM Antennas

Gerino P. Mappatao
De La Salle University, Manila, Philippines

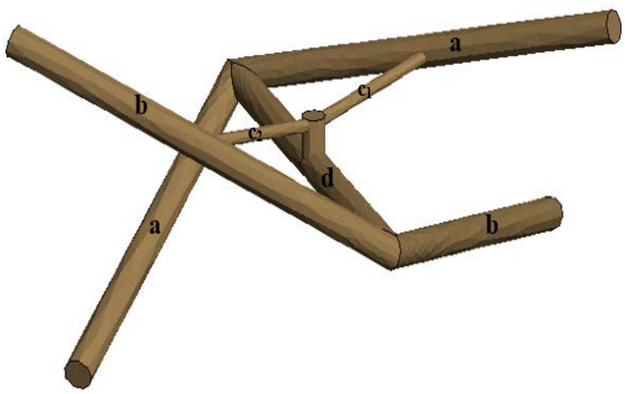
Abstract – It is assumed that omnidirectional basic antenna elements (or bays) in FM antenna systems exhibit a perfectly free-space radiation pattern. However, in actual broadcasting, these basic antennas are side-mounted to a metallic tower affecting the radiation characteristics. This paper presents and discusses the extent of variation on the radiation characteristics of the popular shunt-fed, slanted dipole (SSD) antenna using a leading-edge antenna simulation software. Results of the computer study show that the radiation characteristics of the SSD are severely affected by the metallic tower. The tower effect makes some of these SSD radiation characteristics unable to meet some broadcast requirements set by regulatory bodies.

Keywords - FM antenna, dipole, circular polarization, circularly polarized antenna, antenna optimization.

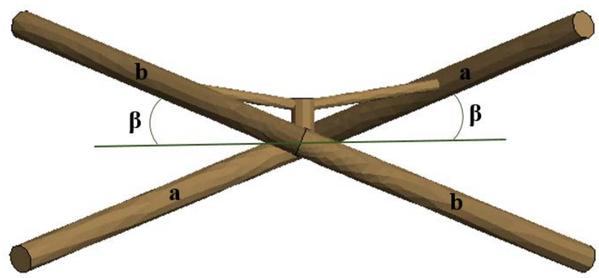
1. INTRODUCTION

The standard polarization type of antennas used in FM broadcasting in the Philippines and most countries in the Americas is horizontally polarized (H-pol). Eventually, the National Telecommunications Commission (NTC) of the Philippines permitted the use of circularly polarized (C-pol) antennas in FM broadcasting. Basically, FM antennas (both C-pol and H-pol) are required to exhibit an omnidirectional pattern on the horizontal plane with a practical circularity of within ±2 dB. Further, they must have at least a bandwidth of 0.2 MHz centered at the carrier frequency. For C-pol antennas, it is required that they produce a vertically polarized (V-pol) power gain component that is not greater than the H-pol component to make the antenna standard remain to be H-pol [1][2][3].

The SSD is a commonly used bay or basic antenna in FM broadcast antenna systems in the Philippines. The SSD was developed to transmit C-pol waves and has the provision to vary the H-pol and V-pol components. Fig. 1 shows an illustration of the SSD. The antenna is basically composed of two V-type dipole antennas. Each dipole antenna is folded to make a 90^0 bend. The arms of one dipole are indicated as **a** and the other dipole has arms indicated as **b** in Fig.1. The dipoles are connected in parallel (shunt) and are fed by a common transmission line. Gamma match is used to match the antenna to the transmission line characteristic impedance via the two feeding arms, $\mathbf{c_1}$ and $\mathbf{c_2}$. The dipoles are supported together by a quarter-length boom, **d** and are oppositely skewed from the horizontal plane by 22.5^0. A similar and more elaborate antenna appears in the US Patent Office entitled The Circularly Polarized Antenna. The patent document specifies the dimensions and physical specifications of the antenna and are shown in Table-1.



(a)



(b)

Fig.1. The Shunt-fed, slanted dipole in (a) Isometric view and (b) Front view showing the different parts and specifications: a - arms of the first dipole; b - arms of the second dipole; c_1, c_2 – feed arms of the first and second dipoles, respectively; d – boom; β – skew angle.

Table-1: SSD parts and dimension values

Part	Dimension Value
Dipole Arm Length (a, b)	Quarter-wavelength
Boom Length (d)	Quarter-wavelength
Skew Angle (β)	22.5^0
Dipole Arm Diameter	1/15 of a wavelength

Omnidirectional antennas are usually developed without taking into consideration the presence and the effects of the vertical tower where these antennas are mounted [4]. Obviously, these metallic towers have effects on the radiation characteristics of the antennas mounted at them. This paper presents the extent of the tower effects on the radiation characteristics of a side-mounted SSD. Specifically, the effects of the tower on the bandwidth, pattern circularity and the power gain relationship between the H-pol and the V-pol components are discussed.

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Further, a discussion is presented showing whether the SSD with the tower still conforms to broadcast requirements described above.

2. METHODOLOGY

To determine the effects of the tower to the radiation characteristics, an advanced antenna simulation software is used. Results from simulation softwares are accepted by regulatory bodies like the NTC and the FCC as proof of performance on the antenna radiation characteristics.

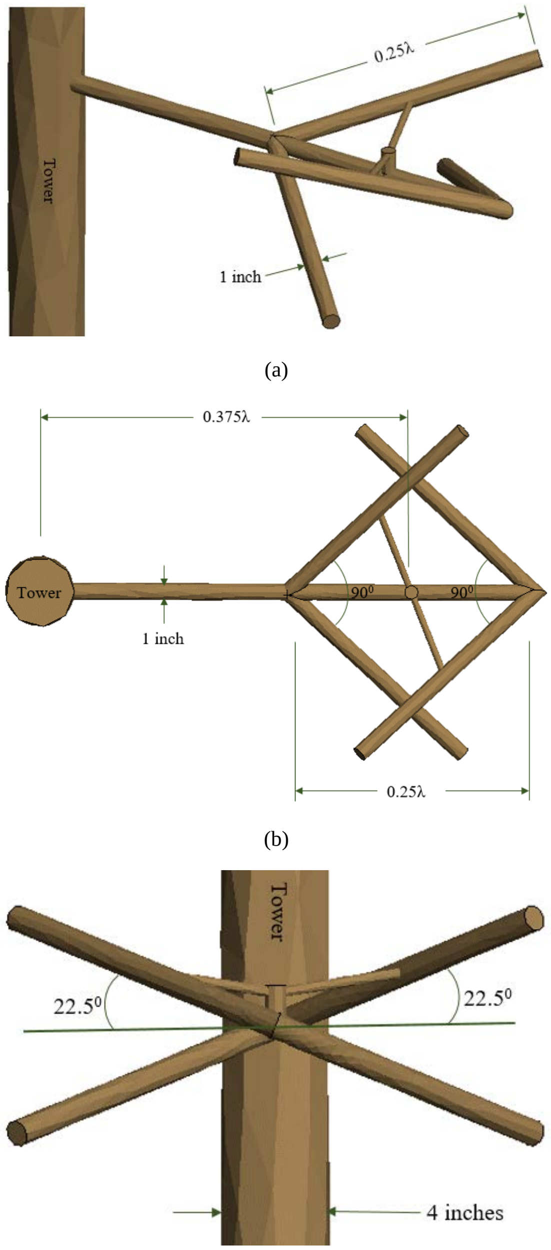


Fig.2. Computer rendition of the SSD in different views: (a) isometric, (b) top and (c) front. The SSD is side-mounted to the center of a metallic tower one wavelength long.

Specifically, FEKO antenna software is used in all numerical computations to determine the bandwidth and the radiation patterns of the SSD with and without the tower. FEKO is an electromagnetic simulation software used for the analysis of wire and three-dimensional structures. It was developed by Altair Engineering and offers powerful methods for the solution of Maxwell's equations, offering users a tool to solve various antenna related problems. The software features are constantly being reviewed and improved for better performance [5].

Fig.2 shows the illustration of the SSD with the tower 0.375λ away from the center of the former. The tower-to-bay-center distance of 0.375λ is the usual value used in practice by broadcasters. In the simulations, the following assumptions are made: (1) the tower has a diameter of 4 inches; (2) the dipole arms are one inch in diameter; (3) the length of each dipole arm is ¼ wavelength; (4) the length of the boom holding the two dipoles is ¼ wavelength; (5) wavelength is computed based on the algebraic mean of the 88-108 MHz FM band.

This paper presents the effects of the tower on the radiation characteristics of the SSD, particularly on the bandwidth, pattern circularity and the domination of the H-pol component over the V-pol component. The bandwidth is quantified by determining the band of frequencies over which the SSD (with and without the tower) exhibits a Standing Wave Ratio (SWR) of less than 2:1. An SWR of 2:1 or greater is generally not acceptable in practice since the reflected power at these values is greater than 10% of the incident power.

The circularity of the radiation patterns of the SSD with and without the tower is also presented and discussed using the polar plots of the total, H-pol and V-pol components gain patterns. Lastly, the polar plots of the radiation pattern components using the electric field patterns of the SSD are used to describe the H-pol over V-pol dominance.

3. SIMULATION RESULTS AND DISCUSSIONS

The radiation characteristics of the SSD with the presence of a metallic tower are presented and compared to the SSD's in free-space in an effort to determine the extent of the metallic tower effect on the bandwidth, pattern circularity and the power gain component. The results of the computer study in this paper are based on the FEKO output on the SSD with the assumptions considered in the methodology.

Fig.3 shows the SWR of the SSD over the FM band, with and without the tower. With the absence of the tower, the SWR is below 2:1 within a bandwidth of 6.4 MHz (94.8 MHz and 101.2 MHz). This bandwidth is far greater than the 0.2 MHz requirement. Further, at 90.4 MHz the SWR spikes to a very high value of 3402.

Considering the presence of the tower, the SWR remains below 2:1 within the frequencies from 93.6 MHz to 101.8 MHz. This relates to an improved bandwidth from a no tower bandwidth of 6.4 MHz to a bandwidth of 8.2 MHz with the tower. Further, the SWR of the SSD with the tower becomes flatter compared to no tower condition; the presence of the tower eliminates the occurrence of the very high value of the SWR encountered in the no tower condition. The highest SWR within the FM band is only 9.43 which occurs at 88 MHz.

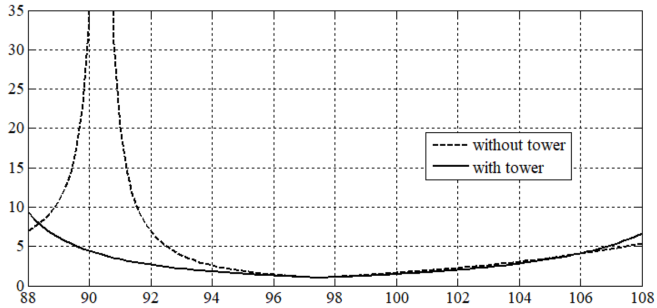
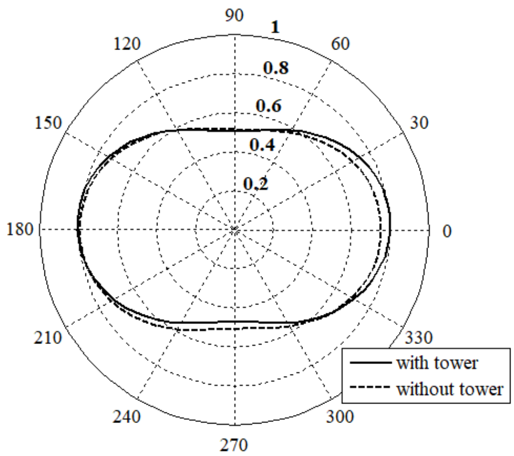


Fig.3. Standing Wave Ratio of the SSD with and without the tower over the entire FM band.

Fig.4 illustrates the circularity of the SSD using its gain patterns with and without the tower on the azimuth. It shows the polar plots of the H-pol, V-pol and total gain components of the SSD in the absence and presence of the tower in the far-field. The tower in Fig.4 is located in the azimuth angle of 270^0.



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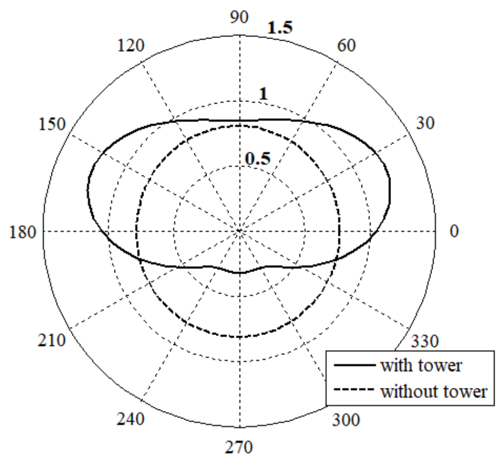

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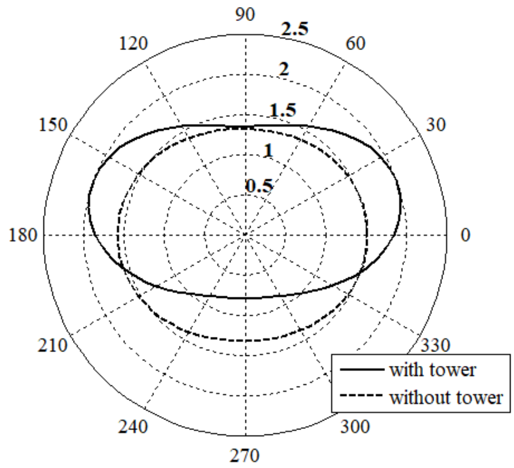


(c)

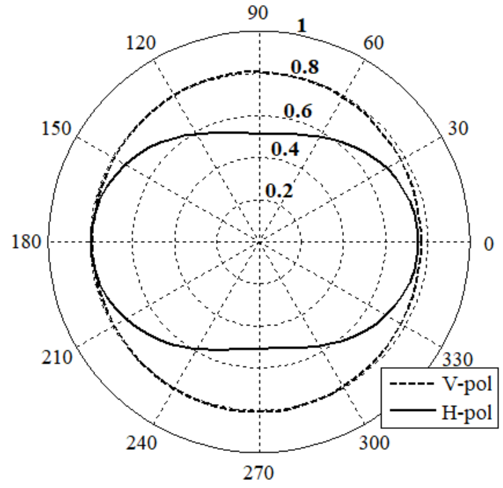
Fig.4. Polar plots of the gains of the SSD with and without the tower to illustrate the tower effects on the pattern circularity of the (a) H-pol component, (b) V-pol component patterns and (c) total gain patterns.

Fig.4(a) illustrates the circularity of the H-pol components for both conditions. As shown, the H-pol with the tower does not have so much difference with the H-pol in the no tower condition. This shows that the H-pol is not very much affected with the presence of the 4-inch tower. In the no tower condition, the H-pol circularity is ±0.977 dB, which corresponds to a minimum gain of 0.508 at 270^0 and a maximum gain of 0.796 at 180^0. When the tower is considered, the circularity becomes ±1.176 dB with a minimum and maximum gains of 0.470 and 0.807, respectively.

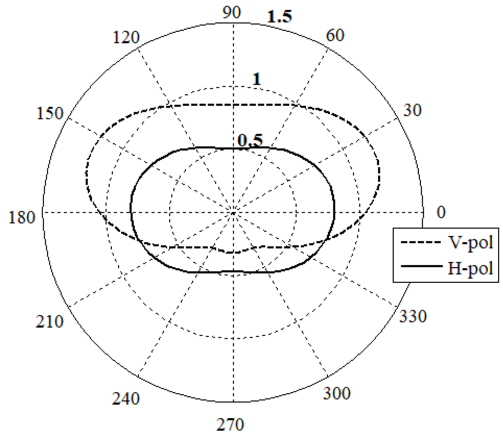
Fig.4(b) shows the V-pol gain components of the SSD with and without the tower. Without the tower, the V-pol gain component has almost perfect circularity of ±0.113 dB where the gain ranges from 0.769 to 0.810. However, when the tower is considered, the circularity is severely affected by the tower making the circularity equal to ±2.923 dB. This value is greater than the allowable practical value of ±2 dB for an omnidirectional antenna.

Fig.4(c) illustrates the circularity of the total gain patterns of the SSD both for the no tower and with tower conditions. The total gain is the summation of the H-pol and V-pol gain components. Numerically, the circularity of the total pattern is equal to ±0.404 dB for the no tower condition. This value is far from the ±2.016 dB circularity of the SSD with the tower.

The performance of the SSD on the superiority of the H-pol component over the V-pol component are illustrated in Fig.5. In the plots of Fig.5, the tower is again located in the azimuth angle of 270^0. The figures shown are the polar plots of the electric fields of the SSD with and without the tower in the far-field and on the horizontal plane. Fig.5(a) shows the components of the electric field patterns of the SSD without the tower.



(a)



(b)

Fig.5. Polar plots showing the circularity of the H-pol and V-pol components of the electric field patterns of the SSD (a) without the tower and (b) with the tower.

As shown, the H-pol is not at all greater than the V-pol, especially towards the directions with azimuth angles around 90^0 and 270^0. Even without the presence of the tower, the SSD fails to achieve the requirement such that the H-pol component is at least equal to the V-pol component. With the presence of the tower, the compliance to the foregoing requirement is far less achieved. Fig.5(b) shows that the H-pol is greater only towards the direction with azimuth angle around 270^0. The results show that the SSD fails in achieving the requirement on polarization components for both conditions of with and without tower.

4. CONCLUSION

The results of the study show that the SSD cannot satisfy all requirements for omnidirectional FM broadcast antennas, especially when the tower is taken into consideration. Foremost, the SSD, with and without the tower, fails to make the H-pol at least equal to the V-pol. Further, the antenna under consideration complies with the circularity requirement only when the tower is not considered. Both the V-pol and the total gain patterns are affected with the presence of the tower, leading to unacceptable values of the circularity. However, the bandwidth of the SSD, with and without the tower, complies with the bandwidth requirement of 0.2 MHz. With these results, the SSD, with or without the tower, does not comply with all the existing standards required of circularly polarized, omnidirectional basic antennas. A further study is needed to make the SSD compliant with the standards.

5. FUTURE SCOPES

The paper presented the limitations of the SSD as a basic antenna in FM antenna systems. To improve its conformance to broadcast requirements on circularity and polarization components, the author suggests the optimization of the SSD on these radiation characteristics. The skew angle, arm lengths, tower distance and arm bending angle are some variables to consider towards the improvement of the SSD performance. Identifying the optimum values of these variables will produce the desired radiation characteristics of the SSD. Further, there are some optimization methods that are developed and published in journals that are applicable for the purpose of optimization [6][7].

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AUTHOR'S PROFILE

Gerino P. Mappatao has received his Bachelor of Science degree in Electronics and Communications Engineering from Saint Louis University, Baguio City, Philippines in 1989. He received the degrees Master of Science and Doctor of Philosophy in Electronics and Communications Engineering from De La Salle University in 1998 and 2012, respectively. He is currently an Associate Professor in the Department of Electronics and Communications of De La Salle University-Manila. He authored and co-authored papers in conference proceedings and journals on antennas, broadcast engineering, wireless communications and image processing.