# Low Cost Ambient Backscatter for Agricultural Applications

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Today, the explosive growth of Internet-of-Things-related applications has required the design of low-cost and ultra-low-power wireless sensors; backscatter communication has been introduced as a cutting-edge technology that could address the above constraints. In agricultural sensing applications, the monitoring of plant water stress is of high importance for smart agriculture. Instead of the traditional ground soil moisture measurements, leaf sensing is an old technology, which is used for the detection of plant water stress. Considering the above topics, this work aims to show the development of a novel tag for environmental leaf sensing which uses ambient backscattering over analog modulated (FM) signals. The work is based on our previous works [1], [2] and it is described how ambient backscatter technology could be exploited for "one sensor/plant" applications in future precision agriculture.

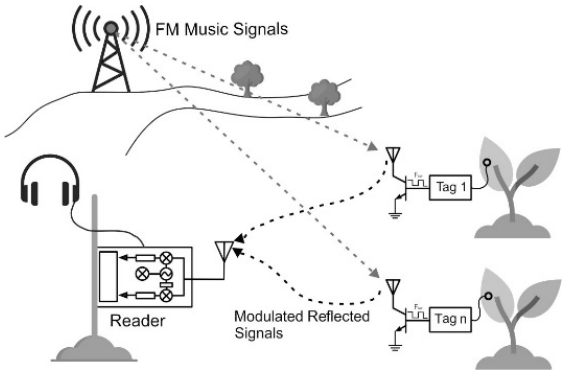


**Figure 1.** Backscatter communication using ambient Frequency Modulated (FM) signals. A commecrial FM receiver can be used for collecting the data.

Ambient backscattering is an idea based on the bistatic backscatter philosophy and could constitute a very promising novel approach for extremely low power and low-cost communication systems. Cellular, television, FM radio and WiFi signals that are typically widely available in urban areas indoors and outdoors during day and night. In our case, as the application is outdoors, far away from industrial centers, only the powerful FM signals are suitable for long-range communication. The tags, shown in Fig. 1, can reflect the ambient music signals from nearby FM stations in order to communicate with a FM receiver. By using ambient signals for backscattering the reader architecture is simplified and its power consumption is reduced dramatically since it does not need a transmitter but only a receiver circuit. The receiver consists of a commercial low-cost software defined radio which downconverts the received signal to baseband and decodes it using an appropriate signal processing algorithm.

The work is based on our previous work [1] that was presented for the first time a novel plant leaf sensor based on a low-cost and low-power backscatter tag. The novel proof-of-consent prototype is batteryless and was powered by a flexible solar panel consuming power around 20 uW. The sensor measures the $T_{leaf}$-$T_{air}$ which is strictly related to the plant water stress. The prototype cost was estimated under 15 USD and was demonstrated monostatic wireless operation up to 2 m distance. Binary amplitude shift keying (ASK) modulation are commonly used for the communication between the tag and reader, such that information is encoded using two states of the amplitude of the reflected carrier wave (CW). Our new tag uses ambient FM signals as a carrier instead of an unmodulated CW signal [2]. Each tag consists of a micro-controller (MCU) with a digital-to-analog converter (DAC) and a power circuit. The tag could collect data from sensors through the ADC and process them. The MCU creates the modulation pulses internally and controls the RF front-end transistor.

[1] S. N. Daskalakis, G. Goussetis, S. D. Assimonis, M. M. Tentzeris, and A. Georgiadis, "A uW backscatter-morse-leaf sensor for low-power agricultural wireless sensor networks," IEEE Sensors J., vol. 18, no. 19, pp. 7889–7898, Oct. 2018.
[2] S. N. Daskalakis, J. Kimionis, A. Collado, G. Goussetis, M. M. Tentzeris, and A. Georgiadis, "Ambient backscatterers using FM broadcasting for low cost and low power wireless applications," IEEE Trans. Microw. Theory Techn., vol. PP, no. 99, pp. 1–12, Nov. 2017.